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Post-glacial fossils from Long Island Sound off West Haven, Connecticut

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This paper is dedicated to Karl Waage, who died on October 18, 1999, 10 days after proofreading the finished draft.

Abstract

In 1957, Holocene marine concretions and mud clasts containing post-glacial fossils of marine invertebrates and land plants were dredged from offshore at Prospect Beach, West Haven, Connecticut, as part of a local beach sand-fill project. Indurated, calcareous concretions, dated at 4530 to 5330 BP, yielded a rich fauna, similar to today's, of bivalves (dominated by *Argopecten* and *Anomia*), gastropods (dominated by *Bittium* and *Nassarius*), and crustaceans, indicating accumulation in a shallow, subtidal environment perhaps 0.3 to 2 m (1 to 6 ft) below mean low water. Megafloral plant remains belonging to eight taxa—including *Fagus grandifolia* (American beech), two species of *Betula* (birch), *Carya* cf. *C. glabra* (pignut hickory), and *Picea* cf. *P. rubens* (red spruce)—indicate the presence of a mixed hardwood forest growing under climatic conditions similar to, or at most only slightly cooler than, those of today. Less numerous, noncalcareous, undated mud clasts are probably younger and contain invertebrates suggestive of life in a protected lagoon. Incorporated peat layers indicate that the sediments accumulated in a protected, shallow water, low energy, subtidal or intertidal environment.

Keywords

Climate, East Haven, marine fauna, flora, Holocene, invertebrates, New Haven Harbor, terrestrial plants, post-Pleistocene, Prospect Beach, radiocarbon dating, global change.

Introduction

Concretions and uncemented mud clasts, both with marine invertebrates and land plants, were found in beach litter at Prospect Beach, West Haven, New Haven County, Connecticut (lat 41°14′46″N, long 72°58′00″W), on the west side of New Haven Harbor. Most of the area (Figure 1) is a 1.6-km-long public beach along Ocean Avenue between Ivy and South Streets. What was originally a coarse shingle beach was made into a bathing beach by addition of sand fill in

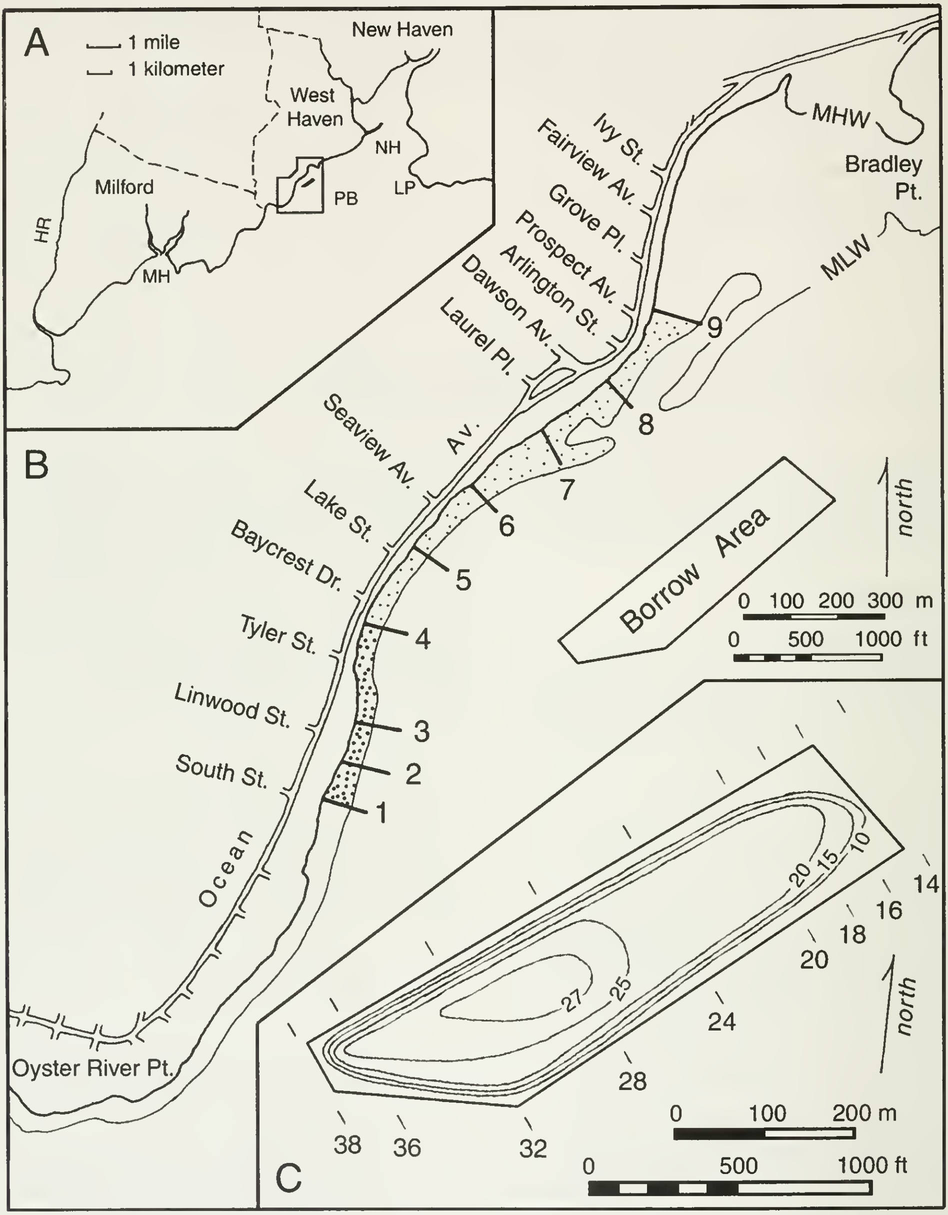


Figure 1

Concretions and mud clasts from Prospect Beach. **A**, index map; **B**, detailed map; **C**, depth contours (ft below MLW) of borrow area based on profiles 14 to 38 of Vesper (1961). Coarse dots, concentrated concretions; fine dots, scattered. Mud clasts between groins 1 and 9. Groins and borrow area modified from Vesper (1961). MHW and MLW modified from U.S. Coast and Geodetic Survey Chart 218 (Connecticut 1964). HR, Housatonic River; LP, Lighthouse Point; MH, Milford Harbor; NH, New Haven Harbor; PB, Prospect Beach.

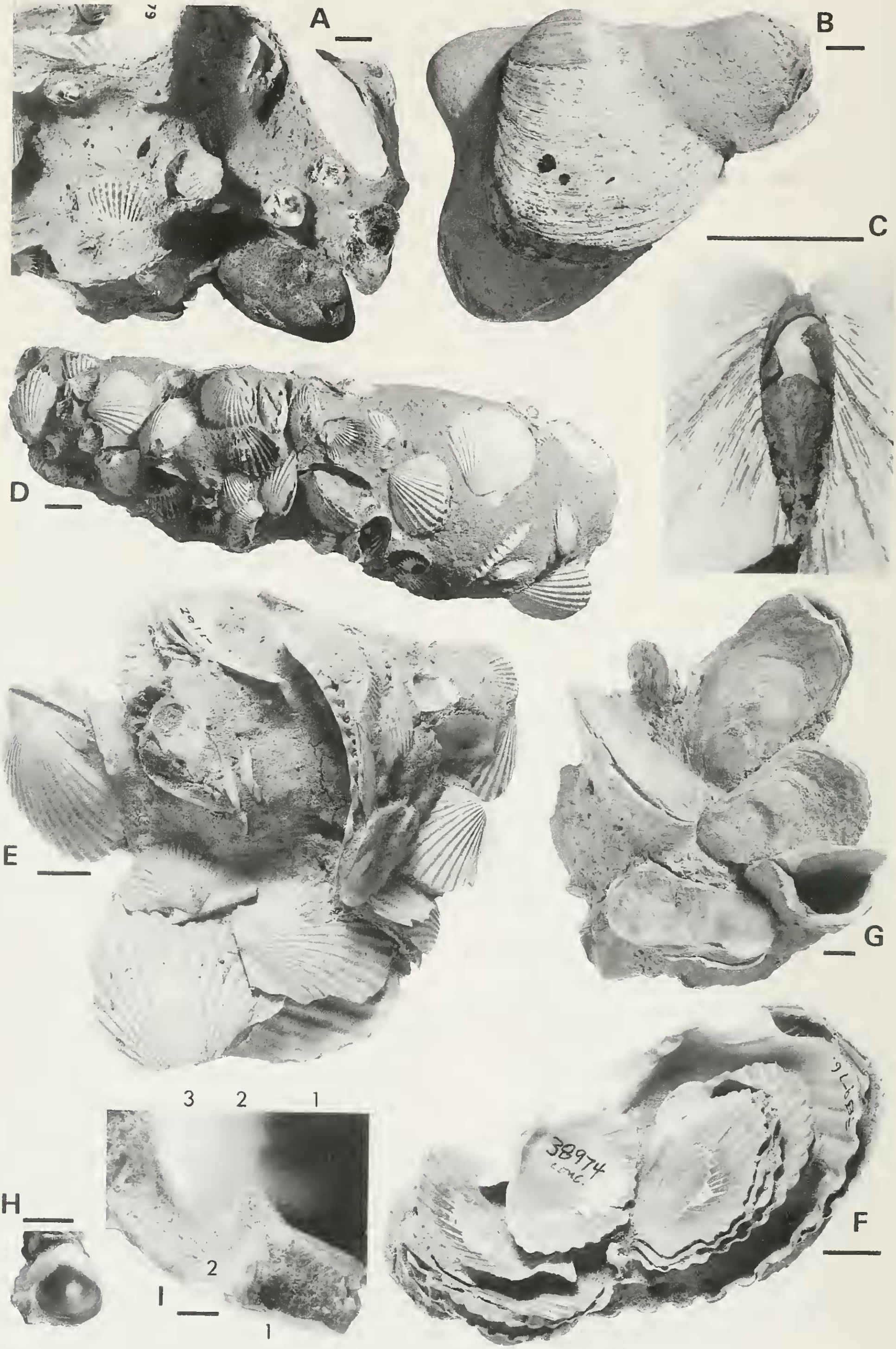
1957 under a cooperative federal and state program to improve and stabilize shoreline areas between New Haven Harbor and the Housatonic River (USACE 1953).

Presence of the concretions was first noticed by Christopher Self of New Haven, who brought one (Figure 2B) to the Yale Peabody Museum for identification in the fall of 1961 (Waage 1962). A collection of 1000 concretions (including cemented shell aggregates) and 46 mud clasts was subsequently accumulated between then and 1968. Renewed interest in this collection prompted re-examination of the intertidal zone at Prospect Beach in the spring of 1999, with the search concentrated between groins 1 and 4 and extending down to 0.3 m below mean low water (MLW), but no additional specimens were found. This report, based on an unpublished 1968 manuscript by Waage, has been completed and significantly enhanced by MacClintock and Hickey. All the invertebrates are catalogued and deposited in the Division of Invertebrate Paleontology, Peabody Museum of Natural History, Yale University (YPM). Associated land plants are catalogued using Division of Paleobotany (YPMPB) numbers but housed in the invertebrate collections. Except for the plants, all figured specimens and those mentioned by number are hypotypes.

Concretions and Mud Clasts

The concretions occur as irregular, ovoid, nodular masses of gray, calcareous sandstone ranging from 3 to 25 cm in length. Clusters of shells held together by concretionary cement are more common than the nodular concretions containing only a few shells or shell fragments. The concretions occur in a variety of shapes and sizes and contain a fauna that varies in abundance and species content (Figures 2–5). The macrofossils are predominantly mollusk shells with *Argopecten irradians* (Lamarck), *Anomia simplex* Orbigny, *Crassostrea virginica* (Gmelin), *Laevicardium mortoni* (Conrad), *Mercenaria mercenaria* (Linnaeus), *Nassarius obsoletus* (Say), and *Bittium alternatum* (Say) the dominant species. Loose shells collected along with the concretionary material in the beach litter were distinguished as "fossils" with certainty only if patches or bits of the thin coating of concretionary matter were found adhering to them. But where the concretions were common, loose, dull brownish-gray valves of *Argopecten*, and some *Mercenaria* valves with a yellowish-gray tint, were also common and probably fossil; locally these constituted as much as 3% or 4% of the molluscan beach litter. About 25 specimens of each of these two genera were found with both valves in place and concretionary material only in the internal cavity.

The concretions consist of sand and silty sand (Wentworth Scale) cemented by microcrystalline calcite. The sand is angular and poorly sorted, with irregular patches of medium and coarse grains occurring in a finer-grained field. Occasional granules and even pebbles up to 4 cm in diameter are present in some of the concretions (Figure 2A). The matrix of the concretionary sandstone consists of calcite admixed with a small amount of allogenic clay. Quartz is the principal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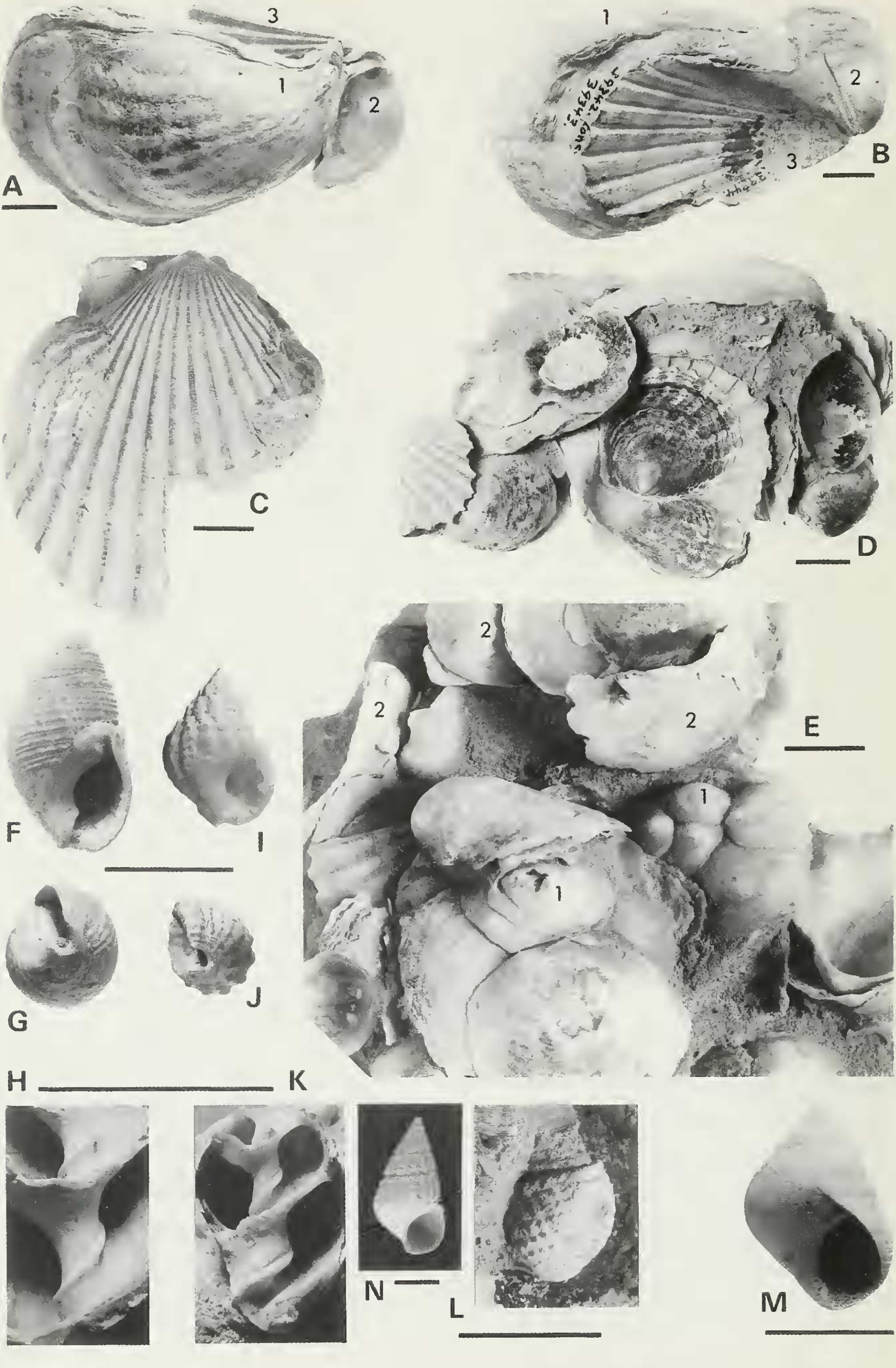
constituent of the sand, and feldspars, weathered to varying degrees, are the next most common group of minerals. Muscovite is the only other major constituent, but a variety of accessory minerals are present. Coarse to fine-grained organic remains also occur, dominated by megascopic plant fragments, but also including pollen, spores, diatoms, foraminifera, insects, and shell fragments. Macrofauna, in addition to mollusks, includes mantis shrimps, crabs, lobsters, barnacles, bryozoa, serpulid worm tubes, boring sponges, and fishes. Macroflora includes wood, nuts, cones and leaves. Some of the small concretions contain only bits of arthropod shell or plant fragments.

The calcitic nature of the cement was established by X-ray diffraction analysis. Concretionary sand in many of the shell aggregates shows a gradation from areas of hard cementation, where the material is compact and dark bluish-gray, to friable material that is medium to light gray. This uncemented, calcareous, silty sand is sticky when wet, and was found adhering in protected areas of shell clusters on many specimens. This material appears to be similar in composition to the cemented sandy silt and may be the parent sediment in which the concretions formed. When washed, it yields very little clay and its stickiness is apparently due largely to gelatinous organic matter. Organic sandy silt is common in the sound today and possibly the soft material on the concretionary shell masses is secondarily derived, but both its degree of compaction and calcareous content favor its being the primary sediment. Bedding is not generally visible in the concretions. However, four do show bedding—one of these has coarse material occurring in a cross-laminated lens.

The less irregular concretionary nodules—those with fewer shells—commonly show some effects of surf-wear and consist only of the harder concretionary material. All of them have a light gray, soft outer rind of weathered material from which most, but not all, of the calcite has been leached. This rind, ranging in thickness from 1 to 3 mm, probably formed after the material was deposited on the beach, with its thickness being proportional to the time spent at the surface exposed to air. Mollusks that

Figure 2

Bivalves. All from concretions. Bar scale 1 cm in all but I. Lighting from different directions. A, *Anomia–Argopecten* concretion with 4.5 cm pebble, assemblage YPM 38762; B, *Mercenaria mercenaria* in concretion found by Christopher Self, assemblage YPM 39092; C, *M. mercenaria,* medial, posterior-oblique view of inner fibrous and outer lamellar ligamental layers, YPM 38811; D–F, *Argopecten irradians*; D, all medium size, 41 of 69 shells exposed on concretion surface have double valves, lot YPM 39358; E, mixed small to large shells, irregularly arranged, none double, lot YPM 39153; F, medium to large shells, sorted and nested roughly by size with larger one on bottom, none double, lot YPM 38976; G, *Crassostrea virginica,* cluster of 12 shells, most double and growing from a common center, lot YPM 39353; H,I, *Laevicardium mortoni* displaying dark to light zones corresponding respectively to contact with fresh concretion (1), weathered rind (2), and sediment outside of concretion (3), YPM 39110; H, whole specimen; I, detail, scale 2 mm.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in life had white or light-colored shells were altered to a dark, amber-brown after encasement in the calcitic concretions. Those shell parts that were outside the concretion remained light. Leaching that produced the rind of the concretions caused the bleaching of the brownish impregnation of the shells that lay within it back to a lighter shade closer to their original color (Figure 2H,I, and an unfigured *Macoma balthica* [Linnaeus], YPM 200033). Color is retained in some of the *Argopecten*, even a few with red concentric banding, but more have been bleached or turned a medium to brownish gray during exposure on the beach. Many *Anomia* retain their luster and yellowish color; others, although retaining their luster, are altered to silver-gray or white. In general, color differences from recent shells of the same species are perceptible but subtle.

Rounded gray, greenish-gray, and pinkish-brown mud clasts, generally ovoid and ranging in length from 3 to 20 cm, occurred sparingly with the concretions in the beach litter. They contain shells of *Argopecten* and other mollusks, though not in an abundance or variety comparable to those in the concretions. They are finer grained than the concretions, uncemented, noncalcareous, and consist chiefly of micaceous silt and fine sand, their "muddiness" being derived chiefly from contained gelatinous organic matter. At least 18 of them exhibit bedding, seen both from differences in grain size and from abundant flat partings of carbonized plant material. All the shells are bleached white, even those enclosed in fresh matrix, and loss of much of their original calcium carbonate has left most of the shells friable. Many of the mud clasts have no rind. In others a light brown rind ranging up to 5.5 mm thick completely encases the sedimentary fragment.

Distribution, Source and Age

The concretions and mud clasts were found only at Prospect Beach, West Haven (Figure 1). The concretions were unevenly distributed along some 1050 m (3500 ft) of shoreline. All but a few of the specimens collected were found along the

Figure 3

Bivalves and gastropods. A–L from concretions, M from mud clast. Bar scale 1 cm in all but N. Lighting from different directions. A,B, two specimens of *Crassostrea virginica* (1 and 2) growing on shell of *Argopecten irradians* (3), YPM 39343, 39351 and 39344, respectively; C,D, *Anomia simplex* growing on shells of *A. irradians;* C, YPM 39355 and 39356, respectively; D, *Anomia–Argopecten* concretion, two *A. simplex* (YPM 39346 below, YPM 39347 above) on inside of *A. irradians* shell (YPM 39348); E, *Anomia* concretion, *A. simplex* growing on other live or dead *Anomia* shells (nested ones [1] probably grew on live shells), includes four byssal plugs (2), lot YPM 39118 (includes all *Anomia* specimens in concretion); F–H, *Nassarius obsoletus;* F, aperture, and G, anterior, YPM 38882; H, detail, columella with one ridge, YPM 38890; I–K, *N. vibex*; I, aperture, YPM 38707; J, anterior, thick outer lip, YPM 38706; K, detail, columella with two ridges, YPM 38794; L, *N. trivittatus*, flattened shoulder visible even though penultimate whorl is mostly gone, YPM 38738; M, *Littorina irrorata*, aperture, YPM 38608; N, *Bittium alternatum*, aperture, YPM 200427, scale 1 mm.

Table 1

Radiocarbon dates (in ^{14}C years) of material from three calcareous concretions determined and reported by Stuiver (1969:566–567).

Laboratory number	Kind of sample	Years BP	Years BC
Y-1129	*Argopecten irradians* shell	4600 ± 90	2650 ± 90
Y-1596	Carbonized wood and leaf fragments	4530 ± 100	2580 ± 100
Y-1783	Calcareous cement of concretions	5330 ± 100	3580 ± 100

350 m (1200 ft) of shoreline between the four groins on the south end of the sand beach between South Street and Baycrest Drive. Search for the material was extended eastward along the coastline around New Haven Harbor to Lighthouse Point and westward to Milford Harbor without finding any trace of the concretions, cemented shell clusters or mud clasts. Spot checks of the beaches between Milford Harbor and the mouth of the Housatonic River were also unproductive.

Outcropping post-glacial marine deposits have not been found above the intertidal zone in the Long Island Sound area. This includes the clay and overlying sand deposits of the Stiles Clay Pit 2 mi south of the North Haven town center (Brown 1930). The marine deposits all lie below sea level, and the gradual rise of sea level since the last glaciation has exceeded any post-glacial crustal rebound south of southeastern Massachusetts (Flint 1957:360). Apparently, the Prospect Beach concretions came from post-glacial marine sediments in the sound itself, either through natural or human agency. The coincidence of their limited distribution with an artificially made beach strongly favors the latter possibility.

Derivation by natural agency is all but ruled out by the low probability that local storm-generated currents could attain enough kinetic energy to cause submarine erosion in a deposit which, as will be explained, is probably not less than 6 m (20 ft) below present MLW anywhere in the vicinity of New Haven Harbor. However, because of the configuration of the sound bottom and the possibility that storm erosion may have occurred along the edge of the flat extending eastward out from the vicinity of Prospect Beach, the possibility of natural agency exposing the source bed cannot be eliminated. Nevertheless, the concretions only came to light since the sand fill was added to Prospect Beach in 1957. Between then and the date of the last collection in 1968 no storms attained hurricane intensity in the New Haven area, not even Hurricane Donna on 12 September 1960 (Brumbach 1965:137). Thus, though lesser storms could have transported the concretions and mud clasts inshore, their highly localized deposition on the southern half of Prospect Beach makes it seem most likely that they were derived from the artificial filling of the beach described below.

The fill for Prospect Beach was

removed from a nearshore borrow area by hydraulic pipeline dredge in the early part of 1957. Nine large-boulder groins were then built to entrap the sand. A subsequent study of the behavior of the fill and borrow area was made by Vesper (1961). Information on the source of the fill and topography of the borrow area is derived from that report and from the study by the U.S. Army Corps of Engineers (1953). The borrow area, lying parallel to the beach between the projections of Lake Street on the south and Arlington Street on the north, was about 250 m (1000 ft) offshore and was about 135 m (450 ft) wide by 600 m (2000 ft) long (Figure 1). Average depth of dredging was 3.6 m (14.5 ft) below the sound bottom; the original depth of the bottom over the borrow area ranged from about 1.2 to 3 m (4 to 12 ft). Profiles by Vesper (1961:5–6) indicate that the base of most of the borrow area was consistently over 6 m (20 ft) below MLW. Approximate contours based on these profiles show that the southwest end of the borrow area was deepest, being generally over 7.4 m (25 ft) and locally over 8 m (27 ft) below MLW.

If, as seems likely, the concretions came from the borrow area, their concentration at the south end of the beach fill and scarcity at the north end suggests that they may have been derived from sediments reached by the dredge only in the deeper southwest end of the pit—that is, about 7.4 m (25 ft) or more below present MLW. The possibility that the concretion source bed was reached only in the deeper southwest end of the borrow area is also supported by information on the depth of beds of comparable age from Clinton, Connecticut, about 36 km (23 mi) due east of Prospect Beach. Bloom and Stuiver (1963:333) graphed the dates and depths of radiocarbon-dated core samples from coastal Connecticut—chiefly from beneath Hammock River Marsh at Clinton—to show the rate of coastal submergence during post-glacial rise of sea level. The samples were mostly of sedge peat that accumulates today in the landward parts of salt marshes and "in estuaries upstream from the high-tide limit of salt water" (Bloom and Stuiver 1963:332). Their data, expressed in a curve of submergence, can be used to show that sedge peat that accumulated between 4000 and 5000 years ago occurs today at depths between 4.4 and 6 m (15 and 20 ft) below mean high water (MHW).

Radiocarbon dates of from 4530 to 5330 BP were obtained for material from three of the West Haven calcareous concretions (Table 1). Compaction of sediment and the fact that the West Haven concretions contain a subtidal fossil assemblage would both tend to increase this depth figure. If sedge peat forms at or just above MHW, a depth factor greater than the 1.9 m (6.4 ft) mean tide range for the area would have to be added to derive the estimated depth for the source bed of the concretions. Using the Bloom and Stuiver (1963:333) submergence curve for 4600 BP and adding 2.1 m (7 ft) for bare adjustment to a subtidal environment yields a depth figure of 7.4 m (25 ft) below MHW, which is most likely minimal for the source bed of the West Haven concretions.

The mud clasts, found uniformly scattered between groins 1 and 9, were prob-

Table 2

List of animals identified in Prospect Beach concretions and mud clasts, arranged by quantity per major group.

Taxa	Concretions	Mud clasts
Bivalvia[a]		
Argopecten irradians (Lamarck)	2614/120[b]	31/1
Anomia simplex Orbigny	2093[c]	9[c]
Crassostrea virginica (Gmelin)	124/29	—/1
Laevicardium mortoni (Conrad)	114/24	11
Mercenaria mercenaria (Linnaeus)	75/36	—
Gemma gemma (Totten)	58[d]/29[d]	—
Modiolus demissus (Dillwyn)	15	5
Ensis directus (Conrad)	7/2	2
Tagelus divisus (Spengler)	5/2	—
Mya arenaria Linnaeus	4/1	—
Macoma balthica (Linnaeus)	1/1	—
Anadara transversa (Say)	3	—
Tellina agilis Stimpson	2	—
Cyrtopleura costata (Linnaeus)	1	—
Indet. Teredinidae	—[e]	—
Gastropoda		
Bittium alternatum (Say)	681	6
Nassarius obsoletus (Say)	93	7
N. vibex (Say)	24	—
N. trivittatus (Say)	2	—
Crepidula convexa Say	17	—
C. fornicata (Linnaeus)	1	—
Eupleura caudata (Say)	3	—
Busycon canaliculatum (Linnaeus)	2	—
Urosalpinx cinerea (Say)	2	—

Continued

[a] Single valve counts, including left and right valves, are given first, followed by double valve count, where applicable.

[b] Fifty-nine of the 120 in two concretions.

[c] Only left valves and 73 isolated byssal plugs counted.

[d] All but two in one small concretion.

[e] Many in one piece of wood.

[f] Unidentifiable with or without appendages, or isolated claws.

[g] Clusters or colonies.

Table 2 continued

Taxa	Concretions	Mud clasts
Polinices duplicatus (Say)	1	—
Mangelia cf. *cerina* Kurtz and Stimpson	3	—
Odostomia bisuturalis (Say)	8	—
Cylichna cf. *oryza* (Totten)	5	—
Retusa canaliculata (Say)	5	—
Seila adamsi (Lea)	1	—
Turbonilla elegantula Verrill	3	—
Caecum pulchellum Stimpson	3	—
Cingula aculeus Gould	5	9
Littorina irrorata (Say)	—	2
Crustacea		
Squilla empusa Say	20	—
Libinia sp.	2	—
Neopanope cf. *sayi* (Smith)	1	—
Cancer cf. *irroratus* Say	1	—
Eurypanopeus cf. *depressus* (Smith)	1	—
Indet. Brachyura[f]	20	1
Homarus americanus Milne-Edwards	2	—
Balanus sp.	11	—
? *Pontocypris edwardsi* Cushman	1	—
? *Cythereis vineyardensis* Cushman	1	—
Indet. Ostracoda	7	—
Insecta		
? Heteroptera	1	—
Indet. Coleoptera	2	—
? Coleoptera	2	—
? Insecta	2	—
Annelida		
Hydroides dianthus (Verrill)	5[g]	—
Bryozoa		
Electra crustulenta (Pallas)	1[g]	—
Schizoporella unicornis (Johnston)	6[g]	—
Porifera		
Cliona celata Grant	25[g]	—

Continued

Table 2 continued

Taxa	Concretions	Mud clasts
Foraminifera		
Elphidium excavatum (Terquem)	37	5
E. e. lidoense Cushman	11	—
E. e. selseyensis Heron-Allen and Erland	4	9
Elphidium sp.	34	—
Haynesina orbiculare (Brady)	22	17
Buccella frigida (Cushman)	14	2
Trochammina inflata (Montagu)	—	1
Ichnofossil		
Indet. polychaete burrows	32	—
Gastropod borings	2	—
Pisces		
Indet. Teleostei	6	—
? Teleostei	3	—

ably dredged up from the same borrow area and placed on the beach at the same time as the concretions. Those that have light brown rinds provide clear evidence that they were originally part of a more continuous layer that was broken up during dredging and then subjected to physical and chemical weathering during their residence on the shore between 1957 and the time of collecting at least five years later. Although not as fossiliferous as sediments collected 11 km to the east by Knight (1933) from "a foot or two below present low tide level" at Killam's Point in Branford, the West Haven mud clasts are similar in physical and chemical composition and faunal content—particularly in the presence of *Littorina irrorata* (Say)—and are therefore inferred to have come from layers stratigraphically above the concretion level and probably less than a meter below MLW. No radiocarbon dates were obtained for the mud clasts.

Invertebrates

A complete list of the fauna is given in Table 2. For counts greater than 200 the number of specimens is approximate. In the concretion fauna, *Argopecten irradians* is apparently the key to the success of the other two major epifaunal bivalves, *Anomia simplex* and *Crassostrea virginica.* It is dominant in total number of shells (2734) and, although no complete set of measurements was made, ranges uniformly in height from 2.5 to 78 mm (YPM 200303 and 200026, respectively). As with today's *A. irradians*, most of the shells are two years old, with a few showing growth into the third year. Of the 2093 *A. simplex* shells, 137 of them (including 73 byssal plugs) are either in life position on *Argopecten* shells or, in isolated left valves, reflect the *Argopecten* ribbing (Figure 3C,D). Most of the rest lived either on other *Anomia* shells (Figure 3E) or on *Crassostrea. Crassostrea* depended heavily on *Argopecten.* Of the 102 paired shells or shell clusters, 35 of them grew on *Argopecten* shells (Figure 3A,B). The rest grew on other *Crassostrea* shells, pebbles, or *Anomia* shells. Based on observations of living *A. irradians* from Buzzards Bay, Massachusetts (both from shallow water and 10.2 m [40 ft]), and Stonington and Niantic, Connecticut, *Crepidula fornicata* (Linnaeus) is one of the dominant elements living on their shells. However, other than one specimen whose pseudo-ribbing reflects its life attached to an *Argopecten* shell, that gastropod is conspicuously absent from the West Haven concretion fauna. With their present distribution from Nova Scotia to the Gulf of Mexico, the paucity of this taxon in the concretion fauna cannot be explained by climatic conditions.

Types of bivalve assemblages in individual concretions range from stacks of shell valves (Figure 2F) to clusters of individuals with both valves of most specimens still attached (Figure 2D,G). Clusters—some dominated by *Anomia* and others by *Argopecten* (Figure 2D)—in which all specimens are of the same size are particularly striking. Many of the single-taxon concretions show a wide range in shell size (Figure 2E). Mixed shell clusters are more abundant than the generically segregated clusters, although either *Argopecten* or *Anomia* is usually dominant. *Nassarius obsoletus* and *Bittium alternatum,* the dominant gastropods in the concretions, occur in all of the kinds of shell clusters. All but one of the 17 specimens of *Crepidula convexa* Say, on the other hand, occur only in clusters of *Anomia.* Reflecting the limited presence of the drilling gastropods *Urosalpinx, Eupleura* and *Polinices,* small drill holes, probably made by *Urosalpinx* or *Eupleura,* were found in one *Argopecten* shell, and one large hole, probably made by *Polinices,* was found in a *Mercenaria* shell. Crustaceans, for the most part, occur within concretions that must be split open to expose the shells (Figure 4D,E). *Squilla empusa* Say, the dominant species, is represented by 20 individuals ranging from juveniles to adults (Figure 4A–C). Of the 25 Brachyura specimens four are identifiable, and six are represented by significant parts of shells with or without attached appendages (Figure 4D–F). The rest are isolated claws. Two claws of *Homarus americanus* Milne-Edwards (Figure 4G) and a few ostracods are also present.

Burrows of infaunal organisms are visible in many concretions. Generally they are circular in cross-section, range in diameter from 1.5 to 5 mm, and are filled with relatively clean sand that is lighter gray than the surrounding sediment (YPM 200415, 200430). Loose beach sand sticking to concretions is recent in origin and is pink. The clean sand in the burrows is therefore not recent. Most of the burrows that have the sediment filling removed show concentric ridges on the burrow walls (YPM 200398, 200416). They were produced after deposition, probably by polychaete worms that burrowed through partially solidified

Table 3

Plant taxa identified in the Prospect Beach concretions. Nomenclature after Little (1979).

Taxa	YPMPB numbers
Conifer wood	40755, 40759, 40760, 40771
Conifer cone—*Picea*? or *Tsuga* (spruce or hemlock)	40764, 40767
Picea sp. cf. *P. rubens* Sargent (red spruce)	40762
Betula nigra Linnaeus (river birch)	40770
Betula sp. cf. *B. lenta* Linnaeus (sweet birch)	40765
Carya cf. *C. glabra* (Miller) Sweet (pignut hickory)	40750, 40751
Chenopodium sp. (goosefoot)	40753, 40754
Fagus grandifolia Ehrhart (American beech)	40768
Platanus occidentalis Linnaeus (sycamore)	40766, 40769
cf. *Scirpus* sp. (bullrush)	40752
Indet. dicot leaf	40757, 40763, 40774, 40775
Indet. monocot leaf (cf. *Poaceae* [grass])	40758, 48033, 45138–45143
Indet. floral receptical	40756

sediments, scratching the burrow walls with their setae and uncini in the process (Warme 1975; Warme and McHuron 1978). The elliptical and sometimes partially flattened cross-section of some of the burrows may reflect either the flatness of the burrowing animal or post-burrowing compaction of the sediment (YPM 200417). Several of the burrows are surrounded by a 2-mm-thick halo of sediment that is more resistant to weathering than the sediment outside the halos (YPM 200409, 200418, 200430). These halos probably reflect the original presence of mucus secreted by the polychaetes during burrowing. Excavations of boring sponges riddle some *Mercenaria* and *Crassostrea* shells.

Foraminifera are common in some concretions but not in all. Three forms of *Elphidium* are dominant, with *Haynesina orbiculare* (Brady) and *Buccella frigida* (Cushman) being less common. No environmental analysis was attempted for the foraminifera.

Epizoans are not common. Serpulids, barnacles and bryozoa occur sparingly on bivalve shells. Recent barnacles, bryozoa, byssal attachment threads of *Mytilus*, and *Polydora* borings that cut into both shell and adjacent concretion material are fairly common and are not to be construed as being part of the concretion fauna.

All of the invertebrate species found in the concretions are living today in Long Island Sound. The fossil fauna as a whole is one of the common, presently subtidal, associations referred to here as the *Argopecten–Anomia* association for its dominant molluscan elements. The preference of *Argopecten irradians* for grass-covered mud to firm sand bottoms in the range from 0.3 to 1.8 m (1 to 6 ft) below MLW has been established by studies in connection with shell fisheries (Gutsell 1931, among others). The U.S. Coast and

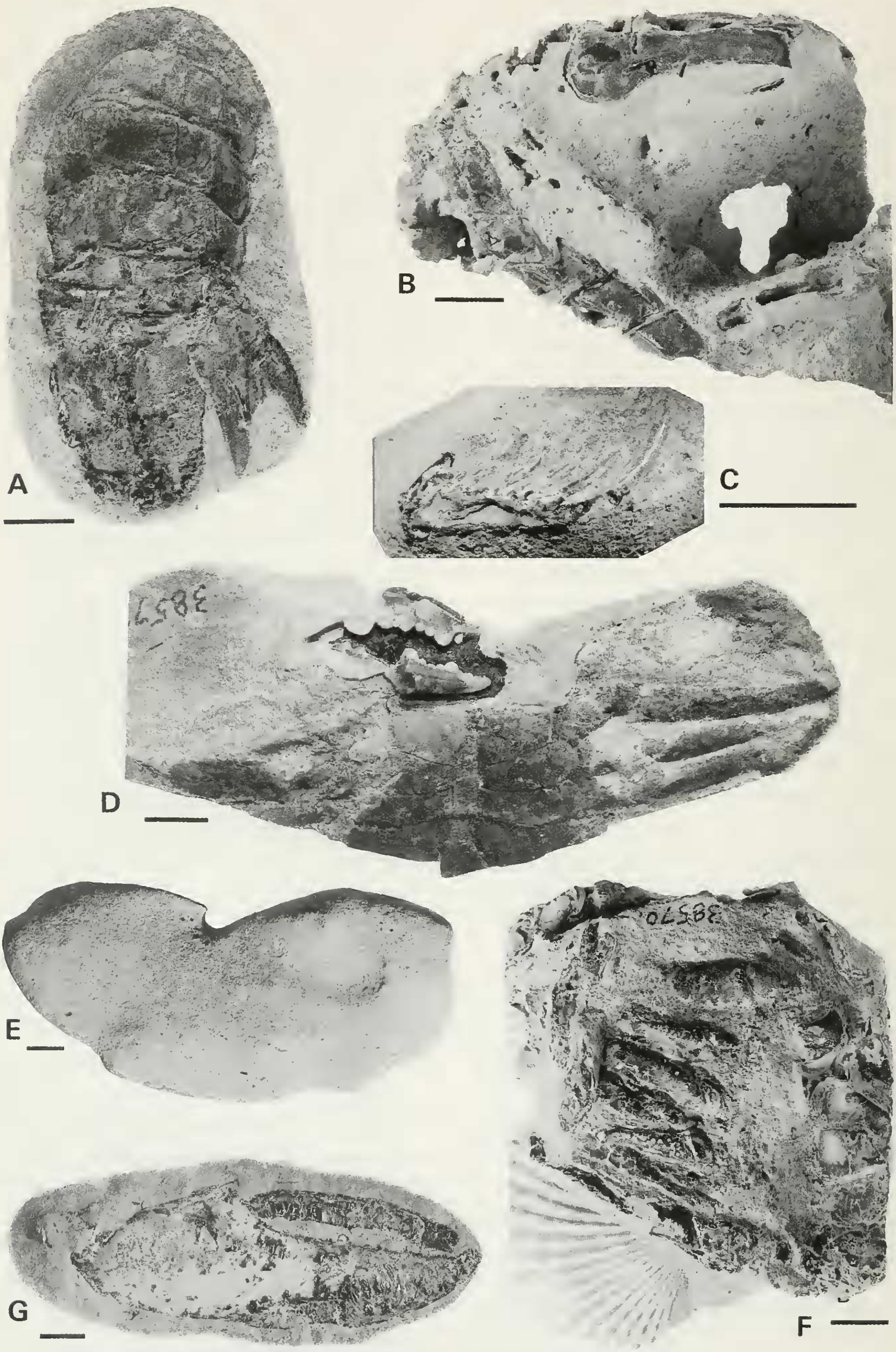
Geodetic Survey Chart No. 218 (Connecticut 1964) indicates the occurrence of local patches of sea grass on the Recent offshore flats in the Prospect Beach area at a depth of about 1.5 m (5 ft) between the shore and the borrow area. Such a habitat is not at variance with the known distributions of any of the other common species in the fossil fauna.

Of the eight species of "micro" gastropods present, all are rare except *Bittium alternatum*; it is by far the dominant gastropod (Figure 3N), occurring in 20% of the concretions, and is particularly abundant in several (e.g., YPM 200311, lot of 74 shells, and YPM 200309, lot of 31 shells, one of which, a gerontic individual, is isolated as YPM 39055). *B. alternatum* today lives on eelgrass, *Zostera marina* Linnaeus, which is most common in the shallow water environment referred to above. The abundance of *B. alternatum* in the concretion fauna indicates a direct link with *Zostera*, and is therefore another good indicator of a shallow water environment. Although 60% of the concretions contain monocot remains, and 97% of the *Bittium* shells are found in monocot-bearing concretions, the plant remains are not *Zostera*, but grass-like leaf fragments that were probably washed into the subtidal environment from an intertidal habitat. *Zostera* itself has little, if any, cuticle and would not tend to be preserved in a sandy environment of deposition.

Of the three species of *Nassarius* (Figure 3F–L) in the fauna, the dominance of *N. obsoletus* and *N. vibex* (Say) over *N. trivittatus* (Say) indicates the presence during life of a muddy sand bottom. *N. trivittatus* (represented by only two shells, with one broken off before enclosure in the concretion) is common today but prefers a clean-sand environment (Morris 1947; Smith 1964).

Recent beach litter on Prospect Beach indicates that the molluscan association living just offshore today is similar to the fossil association in the concretions; only *Laevicardium* is absent locally. The Recent beach litter has a component of *Mya arenaria* Linnaeus, *Mytilus edulis* Linnaeus, *Modiolus demissus* (Dillwyn), *Macoma balthica*, *Mulania lateralis* (Say), and *Littorina* sp., all of which are representatives of environments (muddy or rocky) different from that of the *Argopecten–Anomia* association. With the exception of fragmented, worn shells of three adult *M. arenaria* (and two juveniles), 15 *M. demissus*, and two juvenile shells of *M. balthica*, all of the other species are absent from the concretion fauna. Of the 21 concretions containing *Nassarius vibex*, four also include *N. obsoletus*. The 24 shells of *N. vibex* represent 20% of the nassariids present. Today this species ranges from Cape Cod to the Gulf of Mexico, but is rare in New England (Morris 1947; Smith 1964). This may mean that what is a dominantly a southern form today may have been common in the northern part of its range between 4500 and 5300 BP due to higher water temperature. However, there is not enough information on distribution of invertebrate species within the concretion fauna to speculate further on water temperature.

In the 46 mud clasts the dominant mollusks are *Argopecten irradians* and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Laevicardium mortoni (Table 2). Of particular interest, however, is the presence of five shells of *Modiolus demissus* (one of which [YPM 38610] was not water-worn, and was broken only after collecting) and two of the gastropod *Littorina irrorata* (Figure 3M and an unfigured specimen, YPM 38653). Knight (1933) found these species in the rich molluscan fauna in Branford referred to earlier (YPM Invertebrate Paleontology accession 7719). Based on the present habitat of *L. irrorata* (which ranges from the Gulf of Mexico to New Jersey and does not now live naturally in Long Island Sound) and *Modiolus demissus,* both of which live in quiet water intertidal environments, Knight inferred that the fauna lived in a muddy bottom, shallow subtidal or intertidal, low energy, probably lagoonal environment.

Plants

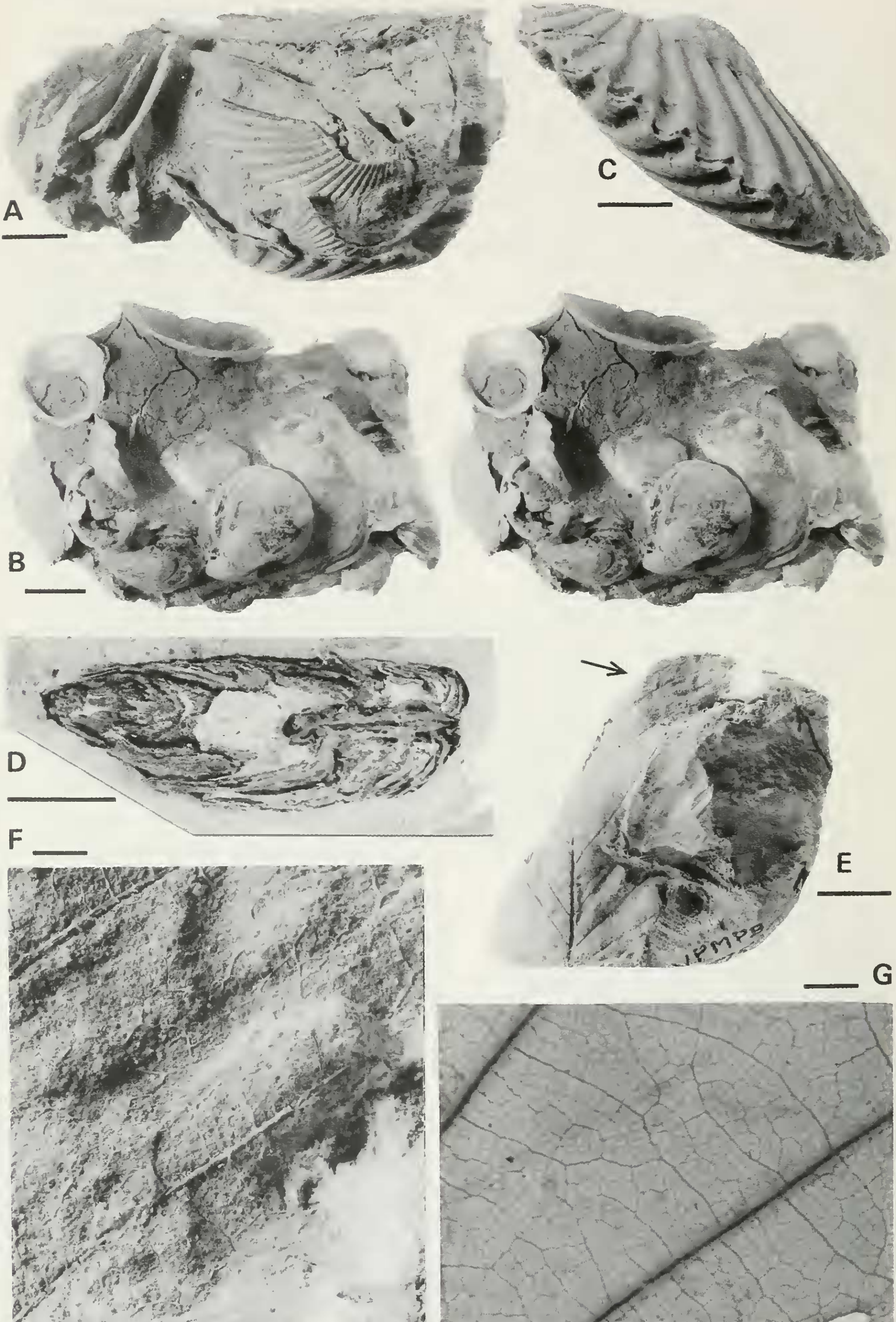
Remains of terrestrial plants are abundant in the concretions, and consist mostly of fragments or clumps of shredded monocot leaves resembling grass or sedge. These are most likely of intertidal origin, based solely on their abundance. Most of the monocot fragments are noncarbonized and very light brownish gray (YPMPB 48033). Other plant remains include partially carbonized wood, charcoal and small plant organs. Pannella (personal communication 1999) also reports the presence of abundant palynomorphs and diatoms, but these were not identified for this study. A list of identifiable megafloral remains, consisting of leaves, nuts and cones, is given in Table 3.

Despite the small number of plant taxa identified in the concretions, this occurrence is important for reconstructing the Holocene vegetational history of southern New England. Although the post-glacial pollen record for the region is well known (Davis 1968), this is only the fourth published account of Holocene megafloral remains from southern New England (Pierce and Tiffney 1986; Peteet et al. 1993; McWeeney 1998). In addition, this flora contains several characteristic species that allow some approximate vegetational and climatic inferences to be made for the time during which they grew.

Of the eight plant taxa that can be identified with reasonable certainty, all but two live in the immediate vicinity of the Prospect Beach site today. However, the presence of two exotics, red spruce and river birch, is of considerable interest

Figure 4

Mantis shrimps, crabs and lobsters. All from concretions. Bar scale 1 cm. Lighting from different directions. A–C, *Squilla empusa*; A, abdominal segments 3 to 6, telson, left uropod, counterpart of dorsal surface, YPM 38558; B, whole animal, right side of carapace and abdominal segments 1 to 5 well exposed, YPM 38555; C, right raptorial claw, YPM 38556; D, undet. male Brachyura, four left pereiopods (three seen well) and four right pereiopods (not seen well, but including cheliped highlighted by ink on matrix behind it) attached to thoracic sternites, ventral, YPM 38573; E, original concretion of D before splitting open; F, undet. Brachyura, five right pereiopods attached or nearly attached to thoracic sternites, ventral, YPM 38570; G, *Homarus americanus,* carpus, propodus, and dacytlus of pinching cheliped, YPM 38588.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in tracing the development of the modern coastal vegetation of Connecticut. A single, sessile, 2-cm-long cone (Figure 5D) was identified as most probably that of red spruce (*Picea rubens* Sargent), based on its narrowly elliptic shape and numerous, thin, tightly appressed, ascending cone scales with longitudinal thicknesses averaging 0.86 mm (n = 4, range = 0.75 to 0.94 mm). Another eastern North American member of the genus, white spruce (*Picea glauca* [Moench] Voss), has cones similar in size and shape to red spruce, but has a more boreal range, with its southern boundary lying in northern New England. In addition, white spruce cones (Yale Herbarium s. n.) are fragile and have papery scales that averaged 0.41 mm thick (n = 10, 1 sigma = 0.1 mm, range = 0.25 to 0.62 mm) as compared to those of red spruce (Yale Herbarium s. n.) measured for this study (mean thickness = 0.97 mm, n = 10, 1 sigma = 0.14 mm, range = 0.75 to 1.12 mm). Although the small size and tightly appressed scales of the Prospect Beach cone suggest that it is somewhat immature, its cone-scale thickness nonetheless falls well within the range of red spruce. The nearest population of this species is a relict stand on the north fork of eastern Long Island (Little 1971).

The second exotic, river birch (*Betula nigra* Linnaeus), is represented by a single partial leaf fragment (Figures 5E,F) with a highly characteristic pattern of lower secondary veins and intercostal venation that matches those features of modern leaves of this species (Figure 5G). Today the northern limit of the continuous range of river birch lies in southern New York. However, two outliers of the species occur in New England: a small, sparse population on the lower Housatonic River near Bridgeport, Connecticut, and an abundant occurrence in the Merrimac Valley of northeastern Massachusetts and southeastern New Hampshire (Little 1971; Jorgenson 1978).

The plant remains in the concretions appear to have been derived from a mixture of forest types, including the Northern Riverine (Kircher and Morrison 1988) or River Birch–Sycamore Forest (Society of American Foresters, Type 61 [Eyre 1980]), on stream banks, and from a mixed hardwood forest on higher stream terraces that included beech, pignut hickory and possibly hemlock.

Climatic parameters for the megaflora were derived using the species overlap method described by Hickey et al. (1988)

Figure 5

Bivalves and plants. All except G from concretions. Bar scale 1 cm in all but D, F and G. Lighting from different directions. A, *Argopecten* concretion with nests of shells at angles to one another, lot YPM 39737; B, inferred armored mud-ball with *Anomia* shells, stereoview, lot YPM 39863; C, double-valved *Argopecten irradians* with *Anomia simplex* (filled with concretionary material) on it in life position, YPM 39447 and 200018, respectively; D, *Picea* sp. cf. *P. rubens*, nearly mature cone, scale 5 mm, YPMPB 40762; E,F, *Betula nigra*, YPMPB 40770; E, leaf fragment, arrow shows area of F; F, detail, scale 1 mm; G, *Betula nigra*, detail of Recent cleared and stained reference specimen, scale 1 mm (National Cleared Leaf Collection 179—U.S. National Herbarium 1201892).

and are shown in Table 4. The presence of red spruce remains at Prospect Beach suggests that the climate was somewhat cooler than at present, but as can be seen from the table, although the mean value for the inferred mean annual temperature (MAT) is 2° lower than at present and the mean annual temperature range (MATR) is 1° higher, the modern values for each of these lie within the limits of error for this analysis. Only the value for the length of the growing season appears to be significantly lower than that of today, but the upper limit of this is only two days below that of the present. Thus, although the flora suggests a somewhat cooler and slightly less equable climate than at present, there is no conclusive evidence for any but a slightly shorter growing season. Plant remains in the mud clasts consist of a single dicot leaf and fragments that resemble grass-like leaves, but no identifications were made due to lack of dates for this material.

Depositional Environments

For the concretion fauna all indications are that the sandy mud environment in which the animals lived was periodically subjected to wave washing during storms, or alternating ebb and flow currents. Many of the single bivalve shells are nested together with their concave sides in one direction. Of the 108 *Argopecten* concretions having six or more shells, 44% had a ratio of 5:1 or better of shells oriented concave in one direction. Several of these clusters have smaller shells nested within larger ones (Figure 2F). Others of the 108 concretions have groups of nested shells oriented at different angles within the same concretion (Figure 5A). For *Anomia,* 30% of the 59 comparable concretions show a similar orientation of shells. These arrangements of *Argopecten* and *Anomia* shells match most closely the masses of vertically oriented shells that accumulate in alternating ebb and flow currents in shallow marine environments described by Reineck and Singh (1980:157, fig. 230).

Some *Anomia* concretions have shells oriented tangentially to the surface of the concretion (Figure 5B), in a configuration that resembles that of armored mud balls (Pettijohn 1975). In his study of storm-disturbed sediments in 14 m (47 ft) of water in Long Island Sound, McCall (1977:255) states that "... fist-size clumps of substratum were eroded out of the bottom and deposited on the surface." Similar "clumps" at the time the West Haven deposit was forming could have rolled around and gathered shells, producing both armored mud balls and some of the irregular clusters of shells.

In the concretion fauna, most of the animals appear to have been transported only a short distance from their living sites and buried quickly. About 20% to 30% of the common bivalves *Crassostrea* (Figure 2G), *Mercenaria* and *Laevicardium* are preserved with both shells attached (Table 2). Among the dominant *Argopecten,* 119 of the shells are double-valved, with most being closed (Figure 5C). Many of the *Anomia* were preserved in life position either on *Argopecten* shells (Figures 3C,D and 5C) or on each other (Figure 3E). Most of the double *Mercenaria* shells have both layers of their

Table 4

Climatic parameters for site of Prospect Beach concretion flora.

Parameters	Present [a]	Past
MAT [b]	10	8 ± 2
MATR [c]	23	24 ± 2
LGS [d]	182	155 ± 25

[a] Source: Visher 1954.

[b] Mean annual temperature in °C.

[c] Mean annual temperature range in °C.

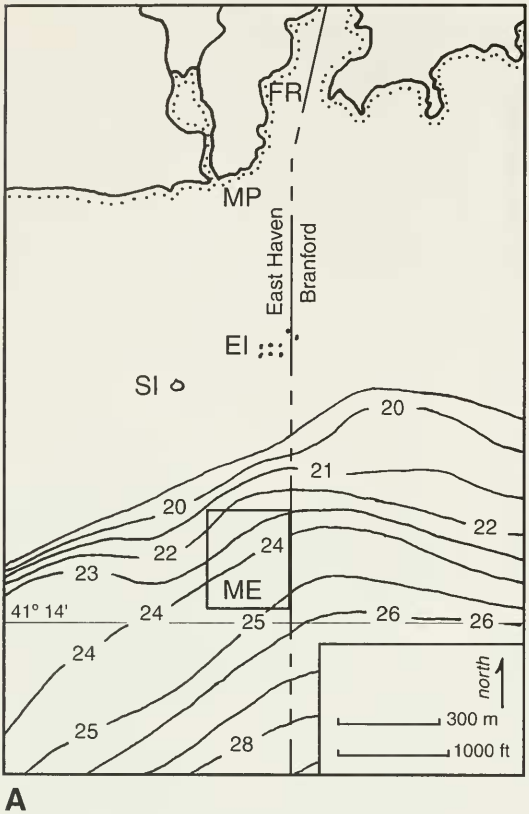
[d] Length of growing season in days.

external ligament preserved (Figure 2C). Neither of the common infaunal bivalve species is preserved in life position. The *Laevicardium* and *Mercenaria* specimens that have both valves attached do not have their long axes parallel to one another in the same concretion. The two concretions with the most (combined total of 59) double-valved *Argopecten* (Figure 2D; Waage 1962:28, top figure, YPM 39360) have shells that range in height from 17 to 28 mm and 16 to 25 mm, respectively. Only one shell, 40 mm high, is larger. All of these individuals, with the one exception, died about half way through their first year of life, perhaps in the same storm. An additional indication of rapid burial is the presence of many articulated crustacean shells (Figure 4).

The lateral extent of bedding and thin peat layers preserved in the mud clasts is indicative of these sediments having been deposited in an area on the sea floor that was very shallow and protected from strong wave action, perhaps behind a sand bar. If, as seems likely, the mud clasts came from above the concretion layer, and given that sea level rose continuously during the time from 5000 BP to the present, it would not have been possible for the mud clast layer to have been deposited in deep water below wave base, currently about 12 m in Long Island Sound. In addition, if the sediments had accumulated in deep water one would expect to find taxa representative of that environment, such as *Yoldia*.

Conclusion

Fossils in calcareous concretions and noncalcareous mud clasts from an offshore borrow area at Prospect Beach, West Haven, Connecticut, were brought onshore by dredging as an unintended consequence of adding sand to a public beach. The concretions are from an inferred depth of 7.4 to 8 m (25 to 27 ft) below MLW; they contain a fauna of 53 identified taxa dominated by *Argopecten irradians* and *Anomia simplex*, and a small but significant flora of eight identified taxa. The invertebrates lived in a muddy bottom, shallow water, subtidal environ-



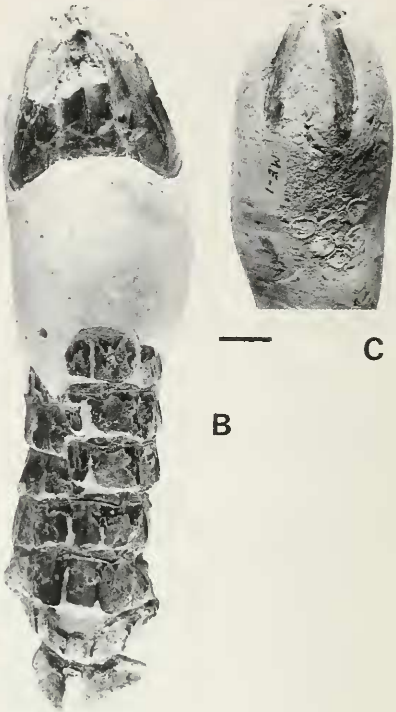


Figure 6

Concretion from East Haven, Connecticut. A, locality map, based on Oyster Grounds lease map (Connecticut 1998). Contour interval of 1 ft based on depths (feet below MLW) given on that map and reproduced here. EI, East Indies Rocks; FR, Farm River estuary; ME, Marc Even lease no. 538 of the Oyster Grounds lease map; MP, Mansfield Point; SI, Stony Island. B,C, *Squilla empusa*, YPM 200984. Bar scale 1 cm. B, carapace, six abdominal segments, telson, dorsal; C, propodi, ventral, and Recent *Balanus* bases on concretion surface.

ment, disturbed from time to time by storm waves and ebb and flow tidal currents, and were buried quickly in shell lag deposits. The concretion fauna is composed entirely of species found living in the area today. Only one species, *Nassarius vibex*, stands out by being common in the fauna. Today this gastropod is abundant in the southern United States and rare in New England. The sparse terrestrial flora suggests a somewhat cooler, less equable climate with a slightly shorter growing season than at present. The common occurrence of *Nassarius vibex* by itself does not provide enough invertebrate evidence to contradict the climatic conditions derived from the terrestrial plants.

During dredging, the noncalcareous mud clasts were torn from what was a continuous sedimentary layer and deposited on the beach with the concretions. Their limited molluscan fauna probably lived and accumulated in a quiet lagoonal environment. One gastropod, *Littorina irrorata,* not found in Long Island Sound today (except by introduction) is present in the fauna.

Several lines of evidence point to the likelihood of a stratigraphic succession of post-glacial faunas and floras in this area. First there is the roughly 750-year gap in the radiocarbon dates between the older (5330 BP) and younger (4530 BP) of the blue-gray concretions and their contents. Then, there is the difference in appearance among the calcareous concretions and the shells associated with them. And finally there are the mud clasts, which, although probably much younger than the concretions, remain undated.

The unexpected find of such rich faunas and floras calls attention to the potential of the nearshore sedimentary record to supply valuable data on the marine and coastal environment during the middle and late Holocene that is available nowhere else in the region. Efforts should be made to visit all such dredging projects in the future. The West Haven site itself would be worth further investigation by collecting from a measured section either after exhuming the old borrow area and collecting by divers or by sinking a large-diameter pipe while hydraulically bringing up material from known depths. Even without the desired stratigraphic controls, the value of this deposit to the scientific community far exceeds its value to the local West Haven community as beach fill—that sand having been washed away long ago.

Acknowledgments

We are indebted to several colleagues in the Yale University Department of Geology and Geophysics from 1968 for special assistance: Minze Stuiver, of Yale's former Radiocarbon Laboratory, for radiometric tests; Giorgio Pannella for information on the fossil pollen, spores and diatoms; and Robert Berner for X-ray analysis of the cement. Ian Speden, when a graduate student at Yale, contributed to collecting and microscopic examination of the concretions; Solene Roming Morris assisted in preparation of microfossils and fossil counts; the photography was done by Al Coleman (Figures 2A,B,D) and William K. Sacco (Figures 2C,E–I, 3 and 4). From the Peabody Museum, Eric Lazo-Wasem helped identify the arthropods; Willard Hartman identified the sponges and serpulids; Ray Pupedis identified the insects; and Lucinda McWeeney helped identify the plants. Ellen Thomas (Department of Earth and Environmental Sciences, Wesleyan University) identified the foraminifera. Stephen Hasiotis (Department of Geology, Indiana State University) identified the polychaete worm burrows. Jon Moore (Honors College, Florida Atlantic University) identified the fish. Donald Rhoads (formerly of the Woods Hole Oceanographic Institution) gave guidance to critical literature and possible sources of pectens on Cape Cod. Sheila Stiles and Joseph Choromanski (Milford Laboratory, National Marine Fisheries Service) provided specimens and valuable information on pectens, and Peter Fisher and Barry Wassel kindly donated pecten shells from Buzzards Bay. Laura Skorina typed the manuscript and provided computer support.

Addendum:
East Haven Concretion

After this manuscript was submitted for publication, we obtained a concretion similar to those from West Haven, but from some 9 km to the east, offshore of East Haven. The concretion was collected about 1995 by Marc Even of West Haven, Connecticut, while dredging for clams at his lease site in East Haven along the Branford town line. The site, Connecticut Department of Agriculture (Aquaculture Division) Lease No. 538, is a rectangle 300 m (N–S) by 250 m (E–W) centered around a point 1150 m S05E of the southernmost tip of Mansfield Point (Figure 6A). The concretion is a dark bluish-gray limestone containing very little silt and sand, and has a 0.5-mm-thick weathered rind. It contains a well preserved, nearly complete specimen of *Squilla empusa* (Figure 6B,C). Living barnacles (Figure 6C) and bryozoa on the concretion indicate that it had been loose on the bottom surface for about a year before collecting, probably brought to the bottom surface during a previous dredging. The bottom at the site slopes from a depth below MLW of 6.5 m (22 ft) in the northwest corner to 7.4 m (25 ft) in the southeast. Given that the hydraulic power dredge used in the operation penetrated to a maximum depth of about 0.37 m (15 in) below the surface, this would place the stratigraphic level of the concretion's source beds over much of the site within the 7.4 to 8 m (25 to 27 ft) depth range below MLW inferred for the West Haven concretions. Thus this find strongly suggests that the West Haven concretion zone has an eastward lateral extent of at least 9 km, and is possibly part of a much more extensive stratigraphic unit along this section of the Connecticut coastline.

We thank Marc Even for bringing the specimen to our attention and for generously donating it to the Peabody Museum. Robert Granfield, the present owner of the lease, kindly loaned us the original map on which the Even lease was plotted.

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